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Review

Taichi exercise for self-rated sleep quality in older people: A systematic review and meta-analysis

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ABSTRACT

Objectives: Self-reported sleep disorders are common in older adults, resulting in serious consequences. Non-pharmacological measures are important complementary interventions, among which Taichi exercise is a popular alternative. Some experiments have been performed; however, the effect of Taichi exercise in improving sleep quality in older people has yet to be validated by systematic review. Using systematic review and meta-analysis, this study aimed to examine the efficacy of Taichi exercise in promoting self-reported sleep quality in older adults.
Design: Systematic review and meta-analysis of randomized controlled studies.
Data sources: 4 English databases: Pubmed, Cochrane Library, Web of Science and CINAHL, and 4 Chinese databases: CBMdisc, CNKI, VIP, and Wanfang database were searched through December 2013.
Review methods: Two reviewers independently selected eligible trials, conducted critical appraisal of the methodological quality by using the quality appraisal criteria for randomized controlled studies recommended by Cochrane Handbook. A standardized data form was used to extract information. Meta-analysis was performed.
Results: Five randomized controlled studies met inclusion criteria. All suffered from some methodological flaws. The results of this study showed that Taichi has large beneficial effect on sleep quality in older people, as indicated by decreases in the global Pittsburgh Sleep Quality Index score [standardized mean difference = −0.87, 95% confidence intervals (95% confidence interval) (−1.25, −0.49)], as well as its sub-domains of subjective sleep quality [standardized mean difference = −0.83, 95% confidence interval (−1.08, −0.57)], sleep latency [standardized mean difference = −0.75, 95% confidence interval (−1.42, −0.07)], sleep duration [standardized mean difference = −0.55, 95% confidence interval (−0.90, −0.21)], habitual sleep efficiency [standardized mean difference = −0.49, 95% confidence interval (−0.74, −0.23)], sleep disturbance [standardized mean difference = −0.44, 95% confidence interval (−0.69, −0.19)], and daytime dysfunction [standardized mean difference = −0.34, 95% confidence interval (−0.59, −0.09)]. Daytime sleepiness improvement was also observed.
Conclusions: Weak evidence shows that Taichi exercise has a beneficial effect in improving self-rated sleep quality for older adults, suggesting that Taichi could be an effective alternative and complementary approach to existing therapies for older people with sleep problems. More rigorous experimental studies are required.

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What is already known about the topic?

- The prevalence of sleep disorder is high in older adults, which seriously affects their quality of life.
- Pharmacological measures may have ambiguous effects and potential adverse reactions for treating sleep disorders.
- Evidence from trials indicates that Taichi exercise may improve sleep quality, but evidence is inconsistent and no systematic review has focused on this topic in older people.

What this paper adds

- There are limited high-quality experimental studies concerning Taichi exercise in improving sleep quality in older people.
- This systematic review and meta-analysis indicates that Taichi exercise may improve self-rated sleep quality in older adults.
- There is a pressing need for more experimental studies to probe into the effect of the easy, cheap aerobic exercise.

1. Introduction

Accounting for 1/3 of every body's life span, sleep is an essential physiological process, with vital restorative functions. With aging, sleep disorder becomes increasingly serious, with reported prevalence of sleep disorders between 9% and 12% in adults, and over 20% and 30% in older adults in western countries (Irwin et al., 2006), and about 35% among old Chinese people (Gu et al., 2010). Sleep disorder can result in serious consequences, including increased fatigue, excessive daytime sleep, impaired functioning, emotional or psychiatric disturbance and declined quality of life, especially in older adults (Crowley, 2011; Irwin et al., 2006; Morin and Benca, 2012; Yang et al., 2012). However, only about 15% of clients seek treatment or consultation (Mellinger et al., 1985; Morin et al., 2011). Among treatment measures, pharmacological therapy remains most common (Glass et al., 2005; Nowell et al., 1997; Smith et al., 2002). Evidence shows that the short-term effect (2–4 weeks) of pharmacological treatment for sleep disorder has been confirmed (Holbrook et al., 2000; Nowell et al., 1997), but the long-term efficacy is still lacking (Morin et al., 1999). What is more, pharmacological treatment may have some adverse effects in older people. The drug may result in daytime confusion, drowsiness, and even the great risk of cognitive impairments, falls, and fractures for older people (Glass et al., 2005; National Institutes of Health, 2005).

Regarding the ambiguous effects and potential adverse reactions of pharmacological interventions, an evidence-based non-pharmacological method is of great importance and interest for older adults with sleep disorders (Irwin et al., 2006). Non-pharmacological approaches have a long history of treating sleep disorders, among which physical exercise is increasingly regarded as an effective way (Gooneratne, 2008; Yang et al., 2012). Several systematic review and meta-analyses have been published to discuss the role of physical exercise in alleviating sleep problems (Kubitz et al., 1996; Montgomery and Dennis, 2002). Generally, the positive effect of physical exercise has been verified in treating sleep disorders, although the conclusions of the studies were not fully consistent with each other. A recent systematic review concluded that exercise training has a moderately positive effect on sleep quality in middle-aged and older adults, and therefore, the physical exercise could be viewed as a complementary and alternative approach for treating sleep problems (Yang et al., 2012).

Taichi, a form of traditional Chinese low- to moderate-intensity mind-body exercise, has a long practicing history for body and mind fitness in East, and is now gaining its great popularity in west countries. A large number of studies have been performed to investigate the role of Taichi in treating chronic conditions. Based on the interventional studies, several systematic reviews have been performed to produce high level evidence of Taichi's effectiveness, in terms of on immunity and infections (Ho et al., 2013), cardiovascular conditions (Lee et al., 2007a,b,c; Ng et al., 2012; Yeh et al., 2009), type 2 diabetes mellitus (Lee et al., 2008a,b,c, 2011a,b), chronic musculoskeletal pain conditions (Hall et al., 2009), aerobic capacity (Lee et al., 2009), blood pressure (Yeh et al., 2008), osteoporosis (Lee et al., 2008a,b,c), osteoarthritis (Lee et al., 2008a,b,c), rheumatoid arthritis (Lee et al., 2007a,b,c), bone mineral density in postmenopausal women (Wayne et al., 2007), and certain cancer care (Lee et al., 2007a,b,c, 2010). Wang et al. (2004) suggested that benefits of Taichi were reported in terms of balance function and strength, cardiovascular and respiratory function, flexibility, immune system, symptoms of arthritis, muscular strength, and psychological effects. Further, a recent systematic review and meta-analysis by Wang et al. (2010) focused on the effects of Taichi on psychological well-being, illustrating that Taichi has a positive effects in psychological well-being, such as reducing stress anxiety, depression and mood disturbance, and increasing self-esteem. Specifically, systematic reviews and meta-analyses have been published concerning older people population, with conclusions that Taichi may have positive effectiveness in improving their balance function and reducing falls (Leung et al., 2011; Liu and Frank, 2010; Low et al., 2009; Maciaszek and Osiński, 2010; Verhagen et al., 2004), increasing their balance confidence (Rand et al., 2011), and in lowering resting blood pressure (Lee et al., 2010).

Concerning Taichi exercise for sleep quality, several randomized controlled trials have been performed, of which conclusions are inconsistent with each other to some extent. On the other hand, previous reviews have shown that Taichi may play some positive role in alleviating sleep disturbance. To our knowledge, however, the limitation of such reviews is that they have not specifically focused on Taichi as intervention topic for sleep (Gooneratne, 2008; Yang et al., 2012), or just considered sleep quality as one of secondary outcomes (Langhorst et al., 2013), which means less clinical significance. No systematic reviews have solely investigated Taichi as main intervention for sleep quality as primary outcome in any group of population, including older people. Therefore, we performed this systematic

review and meta-analysis to explore the effectiveness of Taichi to improve sleep quality in older people. According to de Niet et al. (2009), self-reports of sleep quality reflect the problem from the perspective of patients and therefore deserve highly valued. Considering the easy access, easy application, and clinical importance, we focused on the outcome of self-rated quality of sleep in this study.

2. Methods

2.1. Selection strategy

With no time limit, we performed a comprehensive search of the medical literature in 4 English databases: Pubmed, Cochrane Library, Web of Science and CINAHL (Cumulative Index to Nursing and Allied Health Literature), which have been checked from their inception up to December, 2013. We used following MeSH (medical subject heading) terms and text words when searching: (“Tai Ji” OR “Taiji” OR “Tai Chi” OR “Taichi” OR “Taijiquan” OR “Taichi Chuan” OR “shadow boxing”) AND (“Disorders of Initiating and Maintaining Sleep” OR “sleep” OR “insomnia”) AND (“randomized controlled trial” OR “controlled clinical trial” OR “random*” OR “alloc*” OR “assign*”), which was a summary of search strategy in the 4 databases. We also searched 4 major Chinese databases recommended by domain experts in evidence-based medicine in China, which included: CBMdisc, CNKI, VIP, and Wanfang databases. Subject heading terms and text words included: (“太极” (Taiji) OR “太极拳” (Taichi Chuan)) AND (“睡眠” (sleep) OR “入睡和睡眠障碍” (Disorders of Initiating and Maintaining Sleep) OR “失眠症” (insomnia)”). Finally, a snowball search was done.

2.2. Inclusion criteria

To reach evidence of high grade level, peer-reviewed randomized controlled trials (RCTs) in English and Chinese were selected, excluding quasi-randomized studies (Harbour and Miller, 2001). Further, these studies should meet the following inclusion criteria (PICO format):

P (population): We included the studies which focused on older participants, excluding acute current illnesses. According to World Health Organization, the older population is referred to as 60+ years old (World Health Organization). To capture the main trend of the role of Taichi for sleep quality, studies that examined older people, regardless of their reported baseline sleep quality, were all included. That is, we did not set any threshold for participants’ sleep quality.

I (intervention): Only those papers in which Taichi exercise was considered as main intervention to improve sleep would be included, regardless of the styles of Taichi.

C (comparison): To capture a general trend, studies in which Taichi exercise intervention was compared with following control forms: blank control/placebo/waiting-list/usual care/exercise, were all considered as eligible.

O (outcome): Only those studies in which sleep quality was considered as primary outcomes of interest will be included. We set such criteria for two following purposes: (1) This criteria can help reduce the heterogeneity of included studies; (2) the self-reported outcome is highly valuable to illustrate the problem from the perspective of the clients, and the outcome is easy to assess, although some researchers have argued about their possible bias (de Niet et al., 2009). We considered subjective measures of sleep quality using standardized instruments or scales, e.g., the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989). PSQI is a widely used, self-rated sleep questionnaire to measure sleep quality. A total of 19 questions generate seven components, each with a score ranging from 0 (no difficulty) to 3 (severe difficulty). The components are subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. The scores of seven components are also summed to generate a global PSQI score (ranging from 0 to 21), with a score of more than 5 indicating clinical sleep impairment (Buysse et al., 1989).

2.3. Study outline

First, searches were conducted in the eight databases and relevant titles/abstracts were retrieved. After the duplicate studies were identified and deleted, one reviewer (S.Z.D.) screened the titles/abstracts of candidate articles for potential relevant articles, and a second reviewer (J.S.D.) separately read a random sample of titles and abstracts. After obtaining the full texts of potential relevant studies, two reviews (S.Z.D. and J.S.D.) independently evaluated and selected the articles according to the inclusion criteria for following quality critical appraisal. Finally, a snowball search was done.

During the processes above, any disagreements between the two reviewers were resolved through consensus, if unsolved after contacting authors of the articles. If the consensus could not be reached, the third reviewer (HZ) was consulted for a final decision.

2.4. Quality critical appraisal

The quality of the selected studies was scored using quality critical appraisal criteria for RCTs which was recommended by Cochrane Handbook for Systematic Reviews of Interventions 5.1.0 (Higgins and Green, 2011). The criteria included six items on sequence generation, allocation concealment, blinding, incomplete data outcomes, selective outcome reporting, and other biases (baseline imbalance, early stopping, and source of funding). According to Cochrane Handbook (Higgins and Green, 2011), each item would be rated as “low risk of bias”, “unclear risk of bias”, or “high risk of bias”. In our study, it is not possible to blind the health-care provider. However, it is possible to blind the clients (blinding to the study objectives and outcomes) and the outcome assessors. So, for the purposes of this review, blinding of clients and outcome assessors was considered as adequate. In

general, we considered trials with adequate generation of allocation sequence, adequate allocation concealment, adequate blinding, free from incomplete outcomes, and free from selective outcome reporting to be trials with low risk of bias.

The critical appraisal process was performed by two independent reviewers (S.Z.D. and J.S.D.). Agreement was resolved by consensus meeting between the two reviewers. If disagreement persisted after consensus meeting, a third reviewer (H.Z.) made the final decision.

2.5. Data extraction and analysis

From finally eligible studies, information about subjects, intervention (including styles of Taichi, duration of exercise each time, frequency, and duration of the program), outcome measures for sleep quality, and conclusion was extracted using a standardized extraction form. Thus, the details of the data were tabulated and analyzed. Besides, we stipulated that outcome measures were to be categorized as short-term (up to 12 weeks), medium-term (13–26 weeks) or long-term (over 26 weeks) (El-Sayeh et al., 2006). Data extraction was conducted by two independent reviewers (S.Z.D. and J.S.D.) with discrepancies resolved through consensus.

In systematic review, an overall statistic can be reached by meta-analysis to summarize the effectiveness by integrating the results of several experiments, which will take a broader perspective in a meta-analysis than in a single experiment (Higgins and Green, 2011). All scores were expressed with the means and standard deviations (SD). If SD was unavailable, it was estimated according to methods endorsed in the Cochrane Handbook (Higgins and Green, 2011). Specifically, for group mean, we used the formula in the Handbook to estimate SD with standard errors or confidence intervals presented in the paper (Higgins and Green, 2011).

2.6. Quantitative synthesis of data

In our review, meta-analysis was performed using software RevMan 5.2 (available from the website for free: http://ims.cochrane.org/revman). In meta-analysis, the chi-square and I^2 tests were used to measure statistical heterogeneity (Higgins and Green, 2011). Given $I^2 < 50\%$ and $p > 0.1$, a fixed effect model would be applied. On the other hand, the random effect model would be used if articles were considered clinically similar enough. Otherwise, they would be synthesized with descriptive analysis instead of meta-analysis.

The standardized mean difference (SMD) and a 95% confidence interval (95% CI) of the post-intervention score were calculated by RevMan 5.2. Cochrane handbook shows that the particular definition of SMD used in Cochrane Reviews is the "effect size" known in social science (Higgins and Green, 2011). According to Cohen, effect size of 0.2 is considered small effect, those of 0.5 as moderate, and from 0.8 is large (Cohen, 1988). The results of meta-analysis would be expressed as the pooled effect, with corresponding 95% CI and p value.

3. Results

3.1. Search process

The results of search process are presented in Fig. 1. The literature search of eight databases resulted in 191 potentially relevant articles. Excluded on duplicate, title, and abstract were 156 articles, leaving 35 articles requested for full texts. All 35 articles were available with full texts. These retrieved articles were subsequently evaluated by deep reading. At this stage, 30 studies were excluded mainly due to ineligible study design, ineligible participants, inappropriate interventions, lack of controls, and outcome of primary interest not being sleep. Meanwhile, no articles were found in snow-ball search. Finally, five studies were passed on to quality critical appraisal (Hosseini et al., 2011; Irwin et al., 2008; Li et al., 2004; Liu and Yao, 2010; Nguyen and Kruse, 2012).

3.2. Quality critical appraisal

The risk of bias of the included trials is summarized in the risk of bias graph (Fig. 2) and risk of bias summary (Fig. 3). Two of the five trials (40%) had adequate random sequence generation (Irwin et al., 2008; Li et al., 2004), by computer-generated schedule and random numbers, respectively. None of the other three trials reported on the method of random sequence generation. Two of the five trials (40%) had adequate allocation concealment (Irwin et al., 2008; Li et al., 2004), by using identical sealed, sequentially numbered boxes and avoiding persons who generated the randomization schedule for screening and testing, respectively. The other three trials did not report the use of allocation concealment, and we considered them to be of high risk in this aspect. Only one of the trials reported blinding of participants (Irwin et al., 2008), stating that participants were blinded to the study objectives and outcomes. None of the other four trials reported the blinding of participants. Only one of the trials reported assessor blinding (Li et al., 2004). None of the other trials reported assessor blinding. Regarding incomplete outcome data, two of the five trials reported the use of intention-to-treat approach (Irwin et al., 2008; Li et al., 2004). One trial reported that the post-randomization dropouts were balanced in both groups (Hosseini et al., 2011), and one trial reported there were no post-randomization dropouts (Liu and Yao, 2010). One trial (Nguyen and Kruse, 2012) reported the post-randomization drop-outs, and these patients were excluded from the analysis. So, this trial was considered to be at high risk of incomplete outcome data bias. All five trials reported important outcomes (sleep quality as primary outcome). As a result, the five trials can be considered as at low risk for selective outcome reporting bias. Considering other bias, all five trials had adequately matched participants in the two groups and were free from baseline imbalance bias. For early stopping, one trial reported sample size calculation (Nguyen and Kruse, 2012), and none of the five trials were stopped in advance. The source of funding was described in four trials (Irwin et al., 2008; Li et al., 2004; Liu and Yao, 2010; Nguyen and Kruse, 2012). The sources of funding were academic medical or social science foundations, and we considered the trials to

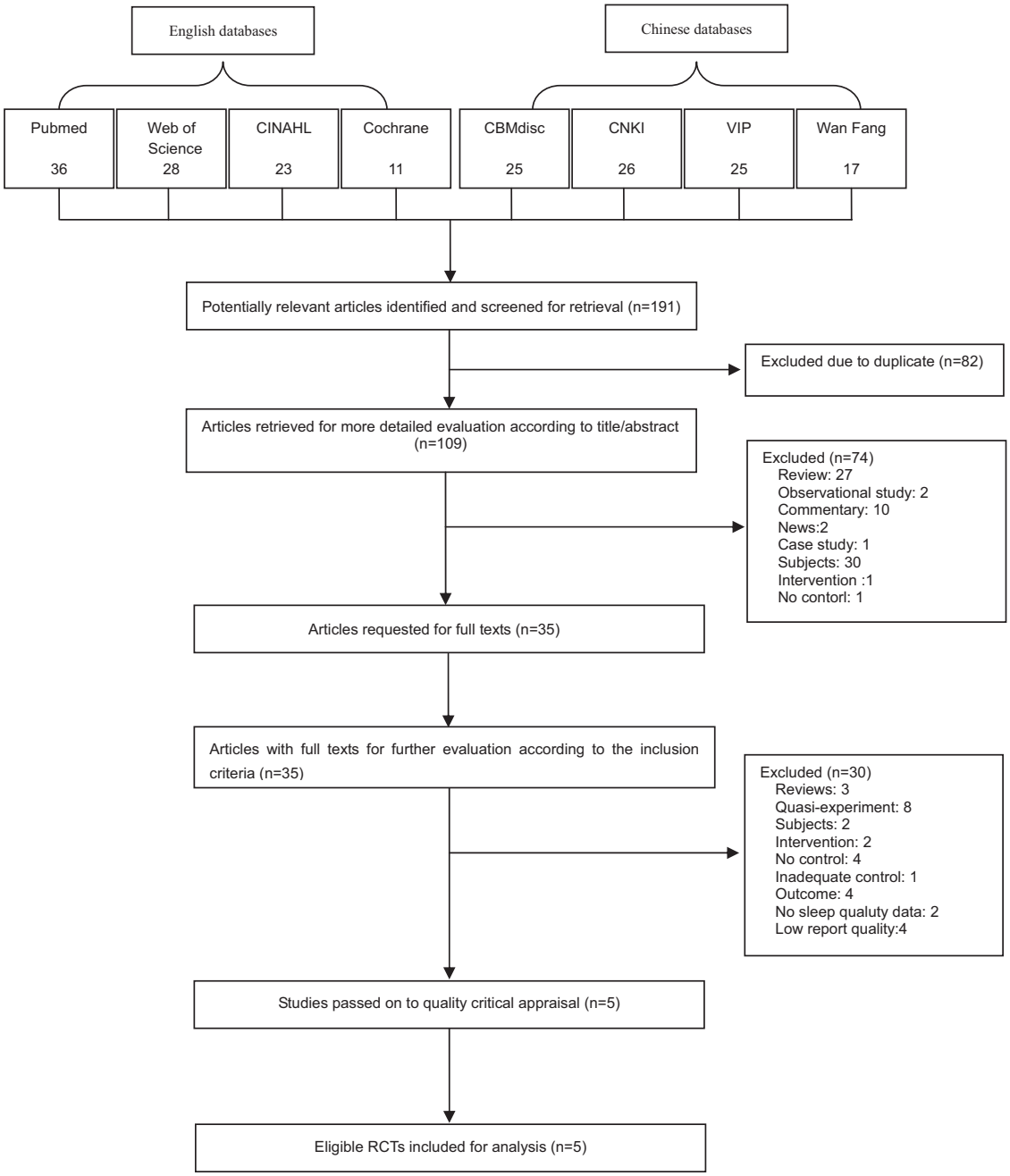

Fig. 1. Flow chart of selection process.

be free from risk of source of funding bias. The source of funding bias was unclear in the trial of Hosseini et al. (2011).

3.3. Characteristics of included RCTs

A total of five RCTs were considered eligible for analysis. The information of their characteristics was listed in Table 1. Overall, the included 5 RCTs were from USA (2) (Irwin et al., 2008; Li et al., 2004), Germany (1) (Nguyen and Kruse, 2012), Iran (1) (Hosseini et al., 2011), and China (1) (Liu and Yao, 2010), respectively.

The studies included a total of 470 participants, among which 243 participants were allocated in intervention groups and 227 in control groups. With explicit inclusion criteria and exclusion criteria, all five trials were performed in community settings. All participants in both groups were community-dwelling older people, with their mean ages ranging from 65.94 and 75.45 years old. Besides, the 470 participants were predominantly the female elderly, with a proportion of 59.1% (278/470). With exception of the study of Irwin et al., the participants of other four trials were reported to be suffering from sleep

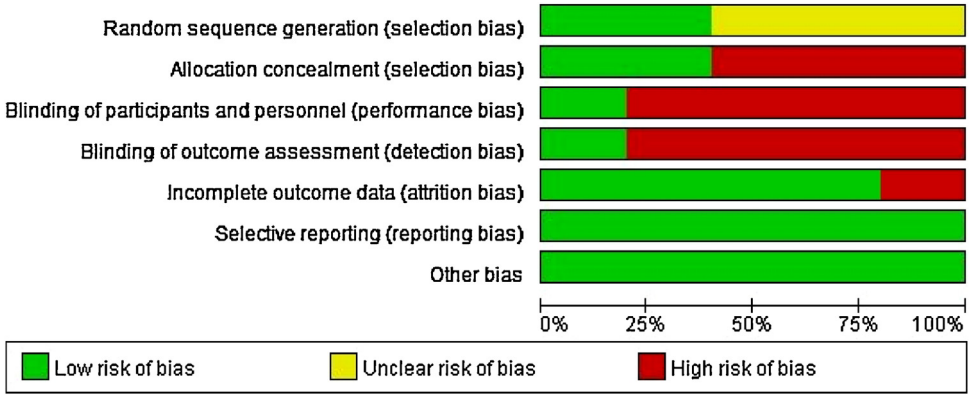

Fig. 2. Risk of bias graph review authors' judgements about each risk of bias item presented as percentages across all included studies.

complaints, with average PSQI global scores over 5, which indicates clinical sleep impairment (de Niet et al., 2009). For the trial of Irwin et al., the participants were stratified into groups with good sleep quality (PSQI global score <5) versus those with poor sleep quality (PSQI global score ≥ 5). To explore the role of Taichi on older people with poor sleep and reduce the heterogeneity among included studies, we used the data of participants with poor sleep quality (PSQI global score ≥ 5).

For the intervention, the session of Taichi exercise varied between 20 and 25 min (Hosseini et al., 2011) and 60 min (Li et al., 2004; Nguyen and Kruse, 2012) each time.

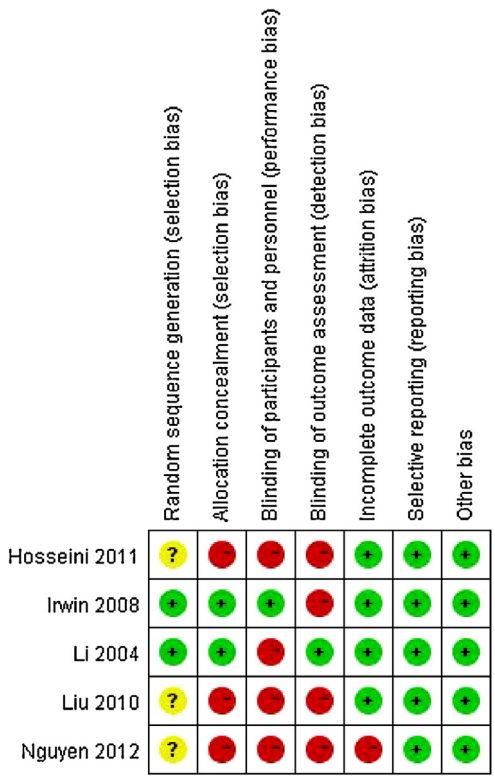

Fig. 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

The frequency of Taichi exercise sessions varied between 2 (Nguyen and Kruse, 2012) and 5 times (Liu and Yao, 2010) each week, with the most common frequency of 3 times per week (Hosseini et al., 2011; Irwin et al., 2008; Li et al., 2004). The duration of exercise program was between 8 weeks (Liu and Yao, 2010) and 24 weeks (6 months) (Li et al., 2004; Nguyen and Kruse, 2012). With exception of the study of Liu and Yao (2010), all of the other four trials explicitly reported that Taichi exercise was guided by experienced, qualified instructors. Specifically, two trials described Taichi exercise in details. The study of Nguyen and Kruse (2012) reported that the version of Taichi exercise in their trial was the 24-form style, including elements of balance, postural alignment, and concentration. The session of Taichi exercise consisted of a 15-min warm-up and 15-min cool-down period. The study of Li et al. (2004) reported that the exercise was based on a simplified Yang style, 8-Form Easy Taichi, and the session included 10-min warm-up, seated light stretches for upper and lower-body muscle groups along with deep abdominal breathing, and 10-min cool-down exercise.

For the attrition and compliance, four RCTs explicitly reported the data. For Taichi group, attrition rates of four trials were reported as 9% (Irwin et al., 2008), 12.9% (Hosseini et al., 2011), 18.75% (Nguyen and Kruse, 2012), and 30.65% (Li et al., 2004), respectively. Two RCTs reported the compliance of Taichi exercise at follow-up period, which were 83% (Irwin et al., 2008) and 93% (Li et al., 2004), respectively.

The control groups in all the trials received either no treatment, maintaining their routine activities (Hosseini et al., 2011; Liu and Yao, 2010; Nguyen and Kruse, 2012), or health education (Irwin et al., 2008), or 1-h low-impact exercise 3 times per week for 24 weeks (Li et al., 2004).

3.4. Outcome pooled analysis

All the included five studies used PSQI as scales, among which three studies (Irwin et al., 2008; Li et al., 2004; Liu and Yao, 2010) reported the data of the seven components of PSQI. We performed meta-analysis in terms of global score of PSQI and its seven components. Besides, we also performed an analysis about other primary outcome

Table 1
Characteristics of included studies.

Study	Participants	Interventions	Measures of sleep	Conclusion
Hosseini H et al./Iran 2011	62 old residents of elderly home with a score of 5 and above, all with PSQI score 5 and above Exp: $n = 31$ (16 males, aged 68.7 years) Con: $n = 31$ (14 males, aged 69.2 years)	Ex = Taichi exercise for 20–25 min * 3 times/week * 12 weeks Con = daily activities	PSQI score	Consistent with other studies, Taichi exercise may have a positive, significant effect on sleep quality of life in older people.
Irwin MR et al./USA 2008	102 healthy older adults Exp: PSQI <5, $n = 29$ (10 males, aged 69.6 years) PSQI ≥5, $n = 30$ (8 males, aged 69.7 years) Con: PSQI <5, $n = 31$ (15 males, aged 69.8 years) PSQI ≥5, $n = 22$ (8 males, aged 70.7 years)	Ex = Tai Chi Chih for 40 min * 3 times/weekly * 16 weeks Con = health education intervention involved 16 didactic presentations on a series of health-related themes.	PSQI score	Tai Chi Chih has a positive role in improving self-rated sleep quality among older adults with moderate sleep complaints, with the potential to ameliorate sleep complaints possibly before syndromal insomnia develops.
Li F, et al./USA 2004	118 community-dwelling older adults with moderate sleep complaints Exp: $n = 62$ (10 males, aged 75.3 years) Con: $n = 56$ (12 males, aged 75.45 years)	Ex = 8-Form Yang style Easy Tai Chi exercise for 1 h * 3 times/weekly * 26 weeks (6 months) Con = low-impact exercise for 1 h * 3 times/weekly * 26 weeks (6 months)	PSQI score ESS	Older adults with moderate sleep complaints benefited from Tai Chi exercise in terms of improving sleep duration and latency, reducing daytime sleepiness.
Liu R, Yao WY/China 2010	82 older adults Exp: $n = 43$ (29 males, aged 65.94, PSQI: 7.92 ± 1.76) Con: $n = 39$ (22 males, aged 66.13, PSQI: 7.84 ± 1.69)	Ex = Shadow-boxing exercise for 30 min * 5 times/weekly * 8 weeks Con = no exercise intervention	PSQI score	Eight-week shadow-boxing exercise can significantly improve the indexes of sleep behavior in older people.
Nguyen MH and Kruse A/Germany 2012	96 community-dwelling elderly Vietnamese Exp: $n = 48$ (24 males, aged 69.2 years, PSQI: 9.38 ± 4.99) Con: $n = 48$ (24 males, aged 68.7 years, PSQI: 8.06 ± 4.09)	Ex = 24-form style Taichi exercise for 60 min * 2 times/weeks * 26 weeks (6 months). Con = routine daily activities	PSQI score	Taichi exercise may have a positive effect on sleep quality, balance, and cognitive performance of the community-dwelling older people in Vietnam.

PSQI: Pittsburgh Sleep Quality Index; ESS: Epworth Sleepiness Scale.

measures of sleep, e.g., Epworth Sleepiness Scale (ESS) in the study of Li et al. (2004).

3.4.1. PSQI global score

All five included studies reported the post-intervention PSQI global score. The effect of Taichi exercise on PSQI global score was examined by pooling data from 381 participants across five trials. The result of meta-analysis showed that, compared with control group, Taichi exercise had a large, significant effect in reducing PSQI global score for older people [SMD = −0.87, 95% CI (−1.25, −0.49), $p < 0.00001$] (Fig. 4).

To explore the specific role of Taichi exercise on sleep quality, we performed a sub-group analysis according to

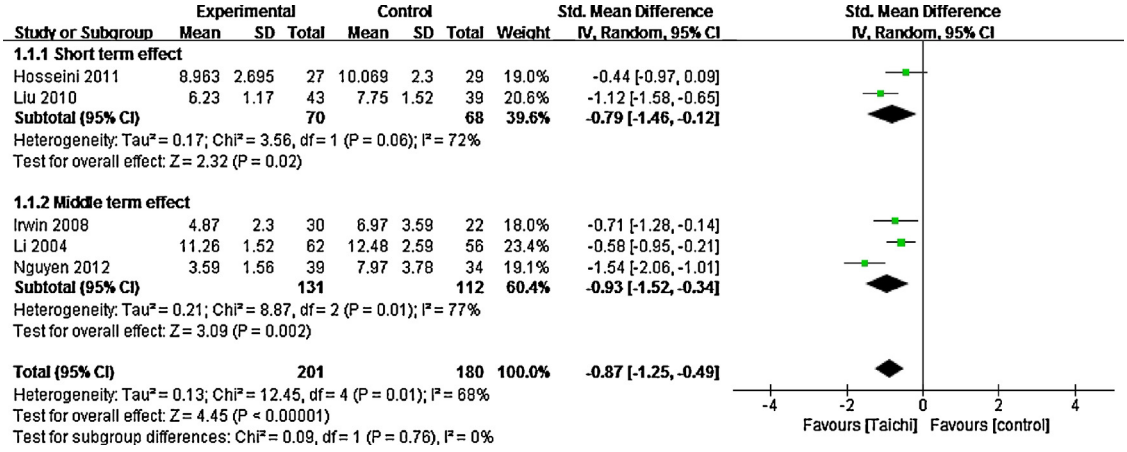

Fig. 4. Forest plot of effects of Taichi exercise on PSQI global score for older people including subgroup analysis.

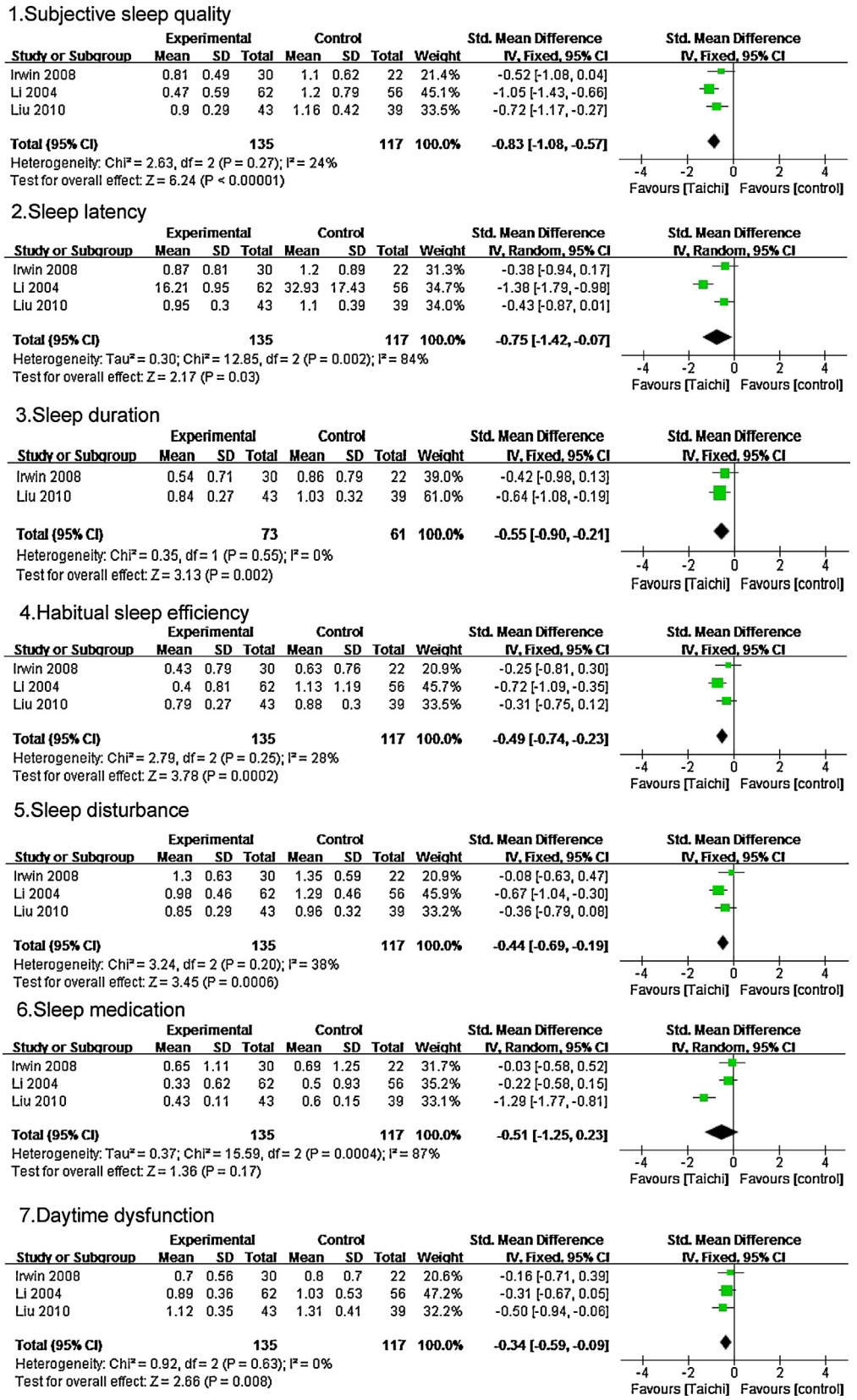

Fig. 5. Forest plot of effects of Taichi exercise on 7 components of PSQI for older people.

the follow-up periods: short-term (up to 12 weeks), medium-term (13–26 weeks) and long-term (over 26 weeks).

There were two articles in which the follow-up periods were considered as short-term period (Hosseini et al., 2011; Liu and Yao, 2010). The result of meta-analysis showed that, compared with control group, Taichi exercise had a moderate, significant effect in reducing PSQI global score for older people at short-term period [SMD = −0.79, 95% CI (−1.46, −0.12), $p = 0.02$] (Fig. 4).

Besides, there were three articles in which the follow-up periods were considered as middle-term period (Irwin et al., 2008; Li et al., 2004; Nguyen and Kruse, 2012). The result of meta-analysis showed that, compared with control group, Taichi exercise had a large, significant effect in reducing PSQI global score for older people at middle-term period [SMD = −0.93, 95% CI (−1.52, −0.34), $p = 0.002$] (Fig. 4).

There were no articles investigating the long-term effect of Taichi exercise.

3.4.2. Subjective sleep quality of PQSI

Three studies (Irwin et al., 2008; Li et al., 2004; Liu and Yao, 2010) reported the data of subjective sleep quality dimension of PSQI. The result of meta-analysis showed that, compared with control group, Taichi exercise had a large, significant effect in improving subjective sleep quality for older people [SMD = −0.83, 95% CI (−1.08, −0.57), $p < 0.00001$] (Fig. 5).

3.4.3. Sleep latency of PQSI

Three studies (Irwin et al., 2008; Li et al., 2004; Liu and Yao, 2010) reported the data of sleep latency dimension of PSQI. The result of meta-analysis showed that, compared with control group, Taichi exercise had a moderate, significant effect in decreasing sleep latency for older people [SMD = −0.75, 95% CI (−1.42, −0.07), $p = 0.03$] (Fig. 5).

3.4.4. Sleep duration of PQSI

Three studies (Irwin et al., 2008; Li et al., 2004; Liu and Yao, 2010) reported the data of sleep duration dimension of PSQI, among which two studies (Irwin et al., 2008; Liu and Yao, 2010) adopt the converted score (0–3) and the study of Li et al. (2004) used the actual number of sleep hours per night. As a result, we calculated the pooled effect by meta-analysis using the data from the two former studies. The result of meta-analysis showed that, compared with control group, Taichi exercise had a moderate, significant effect in improving sleep duration for older people [SMD = −0.55, 95% CI (−0.90, −0.21), $p = 0.002$] (Fig. 5).

Besides, the results of the study from Li et al. (2004) showed that, at the end of 6-month follow-up period, sleep duration of Taichi exercise group increased 0.87 ± 1.041 h from baseline, compared with 0.06 ± 1.68 h from baseline in the low-impact exercise control group, with significant difference ($p = 0.005$).

3.4.5. Habitual sleep efficiency of PQSI

Three studies (Irwin et al., 2008; Li et al., 2004; Liu and Yao, 2010) reported the data of habitual sleep efficiency dimension of PSQI. The result of meta-analysis showed that, compared with control group, Taichi exercise had a small, significant effect in improving habitual sleep efficiency for older people [SMD = −0.49, 95% CI (−0.74, −0.23), $p = 0.0002$] (Fig. 5).

3.4.6. Sleep disturbance of PQSI

Three studies (Irwin et al., 2008; Li et al., 2004; Liu and Yao, 2010) reported the data of sleep disturbance of PSQI. The result of meta-analysis showed that, compared with control group, Taichi exercise had a small, significant effect in improving sleep disturbance for older people [SMD = −0.44, 95% CI (−0.69, −0.19), $p = 0.0006$] (Fig. 5).

3.4.7. Sleep medication of PQSI

Three studies (Irwin et al., 2008; Li et al., 2004; Liu and Yao, 2010) reported the data of sleep medication of PSQI. The result of meta-analysis showed that, compared with control group, Taichi exercise had no statistically significant effect in reducing sleep medication use but a favorable trend [SMD = −0.51, 95% CI (−1.25, 0.23), $p = 0.17$] (Fig. 5).

3.4.8. Daytime dysfunction of PQSI

Three studies (Irwin et al., 2008; Li et al., 2004; Liu and Yao, 2010) reported the data of daytime dysfunction of PSQI. The result of meta-analysis showed that, compared with control group, Taichi exercise had a small, significant effect in improving daytime dysfunction for older people [SMD = −0.34, 95% CI (−0.59, −0.09), $p = 0.008$] (Fig. 5).

3.4.9. Daytime sleepiness

The study of Li et al. (2004) used the scale of ESS to measure the individual's sleepiness by his or her tendency to fall asleep in daily situations. The result showed that after the 6-month intervention, Taichi exercise participants reported greater reduction on ESS score (-2.66 ± 4.24) compared with did control group participants (-0.61 ± 2.68), with significant difference ($p = 0.002$).

3.5. Adverse event in Taichi exercise session

None of the researchers of the five trials reported any adverse effects due to Taichi.

4. Discussion

On the whole, our study provides a review of RCTs examining the effects of Taichi exercise on sleep quality in older adults. Pooled analyses indicate that Taichi exercise has a large beneficial effect on sleep quality in older people, as indicated by decreases in the global PSQI score (SMD = −0.87). Specifically, Taichi exercise has a moderate short-term effect (SMD = −0.79) and a large middle-term effect (SMD = −0.93) in improving the sleep quality in older people. For the components of PSQI, this study showed that Taichi exercise has a large effect in improving subjective sleep quality (SMD = −0.83), a moderate effect in reducing sleep latency (SMD = −0.75) and extending sleep duration (SMD = −0.55), and a small effect in improving habitual sleep efficiency (SMD = −0.49), sleep disturbance (SMD = −0.44) and daytime dysfunction

(SMD = −0.34). For sleep medication, our study showed that Taichi exercise cannot reduce the use of medication significantly, just with a promising trend (SMD = −0.51, 95% CI (−1.25, 0.23), $p = 0.17$). The effect of Taichi exercise in alleviating daytime sleepiness was also observed.

Several previous systematic reviews and meta-analyses have been published to explore the role of non-pharmacological interventions for sleep quality in middle aged and older adults, among which exercise is one of the hot issues. Montgomery showed that exercise may have a role in enhancing sleep quality and an overall quality of life (Montgomery and Dennis, 2002, 2004). The study of Irwin et al. reported that behavioral interventions, including cognitive-behavioral treatment, relaxation, behavioral only, showed similar effects in improving sleep quality for middle aged adults and in older adults 55+ years of age, and participants of both age groups obtained similar robust improvements in sleep quality, sleep latency, and wakening after sleep onset (Irwin et al., 2006). More specifically, a systematic review and meta-analysis examined the effect of exercise training in improving sleep quality in middle-aged and older adults with sleep problems (Yang et al., 2012). In the study, the exercise forms included aerobic exercise (endurance, training, walking, and Taichi), and resistance exercise program, and the result demonstrated that compared with the control group, the exercise group had a better global PSQI score, with a moderately positive effect (SMD = 0.47). Our study focused on a specific aerobic exercise, Taichi, and we found that Taichi has a large beneficial effect on sleep quality in older people (SMD = −0.87). With smaller heterogeneity of intervention among included trials, our conclusion may be more reliable to generalize. For the difference of effect size between this study and study of Yang et al. (2012), we suppose that this may be explained by the difference of interventions and target populations.

The results of our study indicated that with high compliance rate, the older adults have showed their great interest in Taichi. For the safety of Taichi, none of the researchers of the five studies reported any adverse events due to Taichi. There is insufficient evidence to verify that Taichi exercise is unsafe for older adults with sleep disorders.

Regarding the mechanism underlying the effect of Taichi on sleep quality, some theories would make sense. From the perspective of physiology, as a form of aerobic exercise, Taichi exercise is performed slowly and gently with diaphragmatic breathing and relaxation, resulted in declined sympathetic output and enhanced feeling of well-being, which may possibly lead to improved sleep quality (Irwin et al., 2008; Li et al., 2004; Motivala et al., 2006). In addition, some other mechanisms, such as an increasing in energy consumption, endorphin secretion, body temperature, are also beneficial to improve sleep quality (Yang et al., 2012). For psychological effect, the study of Wang et al. concluded that Taichi can improve participants' well-being including "reduced stress, anxiety, depression and mood disturbance, and increased self-esteem" (Wang et al., 2010). So the psychological well-being may also play an important role in improving sleep quality.

In our study, the population of interest is older people, which is the main group suffering from sleep disturbance and has much scope to improve the quality of sleep. To include any possible trial, we did not set certain sleep disturbance threshold for participants in inclusion criteria, just emphasizing that we only included trials in which sleep quality were considered as primary outcome. Four of the included five trials reported that the average scores of PSQI of participants were over 5, which indicated clinical sleep impairment. For the trial of Irwin et al., in which the participants were stratified into groups with good sleep quality (PSQI global score <5) versus those with poor sleep quality (PSQI global score ≥ 5), we also used the data of participants with poor sleep quality for analysis. So in our study, Taichi exercise may have more of a chance of success and changes will probably be greater because there may be no floor effect.

For the quality of the selected studies, only 40% trials reported adequate random allocation and allocation concealment. One trial reported blinding of participants (Irwin et al., 2008) and one of the trials reported assessor blinding (Li et al., 2004). Only 40% trials reported the use of intention-to-treat approach (Irwin et al., 2008; Li et al., 2004). As a result, we are quite cautious in generalizing the findings due to the overall low quality of included studies.

The main limitation of this review was the small number of included trials. We only included five eligible studies. So the conclusion should be considered and generalized with caution. This fact is somewhat consistent with the conclusion of the study from Davey et al., which has found that in Cochrane Database of Systematic Reviews, the median number of meta-analyses per review is six (inter-quartile range 3–12), and the median number of studies included in the meta-analyses with at least two studies is three (inter-quartile range 2–6) (Davey et al., 2011). Secondly, there are two different kinds of comparisons/controls in our study: maintaining routine activities (Hosseini et al., 2011; Liu and Yao, 2010; Nguyen and Kruse, 2012), and active control (Irwin et al., 2008; Li et al., 2004). We did not analyze the trials within each control category separately, which would result in some bias for conclusion because different controls will result in different size of effect. Actually, for the two trials with active controls (Irwin et al., 2008; Li et al., 2004), both of RCTs have revealed that Taichi exercise showed advantages in improving PSQI global score, and some components scores of PSQI, compared with health education (Irwin et al., 2008), or 1-h low-impact exercise 3 times per week for 24 weeks (Li et al., 2004). This means Taichi may be more effective than low-impact exercise or health education. However, this conclusion should be verified further by future studies. Besides, trials reported in languages other than English and Chinese were not included, which may lead to publication bias.

4.1. Practical implications

This review highlights the role of Taichi exercise in improving sleep quality for older people. We found some support for the effectiveness of the systematic use of Taichi exercise to promote sleep quality. To illustrate the clinical

significance of the results, we cited one systematic review concerning the effect of music-assisted relaxation to improve sleep quality (de Niet et al., 2009), according to Thompson (2002a,b). In the review of de Niet et al. (2009), music-assisted relaxation had a moderate effect on the sleep quality of patients with sleep complaints, with an effect size of 0.74 (95% CI [−0.96, −0.46]). According to Hojat and Xu (2004), effect size is a scale-free index, and can be uniformly compared and interpreted across different studies with different sample sizes and the original scales of the variables. Thus we can approximately estimate the clinical significance of Taichi on sleep quality, with an effect size ratio of 0.87 versus 0.72 for Taichi versus music-assisted relaxation. More specifically, according to the effect size criterion for clinical significance of 0.50 level suggested by the National, Institute for Healthand Clinical Excellence (NICE) in their guidelines for the treatment of depression (2004), the effect sizes of global PSQI score (SMD = −0.87), PSQI subjective sleep quality (SMD = −0.83), sleep latency (SMD = −0.75) and sleep duration (SMD = −0.55) may be considered of clinical significance, while the effect sizes of PSQI habitual sleep efficiency (SMD = −0.49), sleep disturbance (SMD = −0.44) and daytime dysfunction (SMD = −0.34) may be regarded as below the criterion for clinical significance, though they can be considered as small effect for statistical significance.

Since no adverse events were reported, health care providers including nurses can use the findings in their practice to generalize the exercise. Taichi exercise is a safe, cheap, and easy intervention in community settings which may be used to alleviate sleep conditions in older people (Li et al., 2001, 2004).

5. Conclusion

Overall, as a relatively safe aerobic exercise, Taichi exercise may have a large beneficial effect on sleep quality in older people, as indicated by decreases in the global PSQI score, as well as its sub-domains of subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbance, and daytime dysfunction. Daytime sleepiness might also be improved. These findings suggest that Taichi could be an alternative or complementary approach for treating older people with sleep problems in community settings, with varying potential clinical significance. However, more rigorous evidence is required to reach a more reliable conclusion.

Conflict of interest

No conflict of interest has been declared by the authors.

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